
CLAIMS

[Claim(s)]
[Claim 1] In the surface layer property measuring method which measures the property of the surface layer of this analyte from two or more acoustic signals received from analyte The group delay of the frequency of the arbitration between two acoustic signals in said two or more acoustic signals is found. The measuring method of the surface layer property characterized by changing the group delay of the frequency of the arbitration between said two acoustic signals searched for into a surface layer property based on the relation between the group delay found beforehand and said surface layer property, and measuring the property of the surface layer of analyte.
[Claim 2] The measuring method of the surface layer property according to claim 1 characterized by the relation of said group delay and surface layer property which were searched for beforehand being the transform function changed into the property of a surface layer from group delay.
[Claim 3] The measuring method of the surface layer property according to claim 1 or 2 characterized by said surface layer property being hardening layer thickness.
[Claim 4] It is the surface layer property measuring method according to claim 2 which said surface layer property is the depth direction distribution of the physical properties of a surface layer, and is characterized by for the frequencies of said arbitration being two or more frequencies, and being a transform function with which said transform function relates the group delay of two or more of said frequencies, and the depth direction distribution of said physical properties according to the depth direction energy distribution.
[Claim 5] It is the surface layer property measuring method according to claim 2 which said surface layer property is the depth direction distribution of the physical properties of a surface layer, and is characterized by for the frequencies of said arbitration being two or more frequencies, and being a transform function with which said transform function relates the group delay of two or more of said frequencies, and the depth direction distribution of said physical properties according to the depth direction sound pressure distribution.
[Claim 6] said surface layer property -- the depth direction distribution of the physical properties of a surface layer -- it is -- the frequency of plurality [frequency / of said arbitration] -- it is -- said transform function -- the group delay of two or more of said frequencies, and the depth direction distribution of said physical properties -- the depth direction -- a variation rate -- the surface layer property measuring method according to claim 2 characterized by being the transform function associated according to distribution.
[Claim 7] A surface layer property measuring method given in claim 4 characterized by said surface layer property being hardness distribution of a surface layer thru/or any 1 term of 6.
[Claim 8] In the surface layer property measuring device which measures the property of the surface layer of this analyte from two or more acoustic signals received from analyte A group delay operation means to compute the group delay between two acoustic signals of the arbitration which received in a different location among two or more acoustic signals received with a sound reception means to receive the acoustic signal which spreads said analyte front face, and this sound reception means, The surface layer property measuring device characterized by having a surface layer property conversion means to change into the surface layer property of this analyte the group delay calculated with this group delay operation means.
[Claim 9] The surface layer property measuring device according to claim 8 by which it is characterized [which is characterized by said sound reception means coming to contain a means to transmit an acoustic signal].
[Claim 10] The surface layer property measuring device according to claim 8 characterized by said surface layer property conversion means coming to contain the memory in which the relation between hardening layer thickness and group delay was stored, and the arithmetic circuit which calculates hardening layer thickness from said group delay based on said relation memorized by this memory.
[Claim 11] The surface layer property measuring device according to claim 8 characterized by said surface layer property conversion means coming to contain hardening layer thickness, the memory in which the relation of the sonic rate of change to a base material was stored, and the arithmetic circuit which calculates hardening layer

thickness from said group delay based on said relation memorized by this memory.
[Claim 12] The surface layer property measuring device according to claim 8 characterized by said surface layer property conversion means coming to contain the memory in which the hardness of analyte and the relation of group-velocity rate of change were stored, and the arithmetic circuit which calculates the hardness distribution on the front face of analyte from said group-velocity rate of change based on said relation memorized by this memory.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the approach and equipment which measure the property of an analyte surface layer by un-destroying using an acoustic signal.
[0002]
[Description of the Prior Art] The method of using sonic change of a surface wave as an approach of measuring the depth direction distribution of the thickness of a surface layer or the properties (hardness etc.) of a surface layer by un-destroying is learned. This approach uses that the acoustical property of a surface layer, i.e., the elastic modulus and consistency of a surface layer, differs from the base material section. That is, the rate that a surface wave spreads the surface layer and the base material section of a surface wave with the thickness of a surface layer since 90% or more of energy exists in the depth direction from the front face of analyte at one wave of within the limits changes. Consequently, it will be said that the acoustic velocity of a surface wave changes according to the thickness of a surface layer.
[0003] There is an approach indicated by JP,62-277554,A as a measuring method using this principle. By this approach, the analyte front face was made to spread a surface wave, it was received by one side, acoustic velocity was searched for from the propagation time in the meantime, and the thickness of a surface layer is measured from the sonic rate of change on the basis of the acoustic velocity of a base material. However, in a surface wave, the phenomenon which the way of a RF spreads according to the distributed phenomenon in which acoustic velocity changes with frequencies, more quickly than low frequency arises, and it changes or spreads with propagation. For this reason, by the above-mentioned approach, highly precise propagation-time measurement is difficult.
[0004] As a means to solve this, there is a method of searching for acoustic velocity from the propagation time for every frequency, and the approach announced by nondestructive inspection (39th volume No. 2 pp. 99 -103) ″nondestructive evaluation of the surface layer by the Rayleigh wave″ is learned as this example. By this approach, the phase velocity of two or more frequencies is measured, and the depth direction distribution of the elastic modulus of a surface layer is calculated from that rate of change.
[0005]
[Problem(s) to be Solved by the Invention] By the way, although the phase velocity of the wave number is measured two or more rounds with the above-mentioned conventional technique, measurement of the phase time delay between the points receiving [2] is needed for this. About both the received waves received at said point receiving [2], a phase time delay is computed from the phase contrast of a certain frequency component. This process is explained with reference to drawing 10 . In this drawing, the wave of the angular frequency omega in the receiving point 2 presupposes that there is phase lag of thetar (omega) to the wave of the angular frequency omega in the receiving point 1. however, ** which the trough A of the receiving point 1 is the trough B of the receiving point 2 in fact, or is trough B' or are other troughs which 2pi left ready several times -- it is not clear. That is, the optionality of 2npi (n is an integer) exists in phase contrast theta (omega), and it is phase contrast theta (omega). theta(omega) =thetar+(omega) 2npi ... (1)
It can express. On the other hand, it is phase time delay taup (omega). taup =(omega) theta (omega) / omega ... (2)
Since it is come out and computed, it is too influenced of the optionality of 2npi. For this reason, it is necessary to solve this problem with another means.
[0006] So, by the well-known example of said latter, where the condition and surface layer of a base material are formed, a means to ask the known acoustic velocity and the known propagation path length of a base material for near phase contrast, and to ask only for the gap between - pi-pi from the phase contrast by measurement from a premise that only the difference within 2npi is produced in the phase contrast of received waves is adopted.

However, when the case where the location of transmission or reception is unstable, and a propagation path are curved surfaces and measurement of propagation path length is difficult, near phase contrast cannot be known with said means, as a result measurement of the elastic modulus (hardness) of a surface layer becomes difficult.
[0007] This invention was made in view of the actual condition of such a conventional technique, and the purpose is in offering the approach and equipment which can measure the property of a surface layer, even if propagation path length is strange.
[0008]
[Means for Solving the Problem] In the surface layer property measuring method with which the 1st means measures the property of the surface layer of this analyte from two or more acoustic signals received from analyte in order to attain the above-mentioned purpose The group delay of the frequency of the arbitration between two acoustic signals in said two or more acoustic signals is found. It is characterized by changing the group delay of the frequency of the arbitration between said two acoustic signals into a surface layer property, and measuring the property of the surface layer of analyte from the relation between the group delay found beforehand and said surface layer property.
[0009] In this case, the transform function changed into the property of a surface layer from group delay is introduced as relation of the property of said group delay and surface layer for which it asked beforehand, and hardening layer thickness is measured as a surface layer property.
[0010] Moreover, when measuring the depth direction distribution of the physical properties of a surface layer as said surface layer property, the frequencies of said arbitration are two or more frequencies, introduce the transform function which associates the group delay of two or more of said frequencies, and the depth direction distribution of said physical properties according to the depth direction energy distribution as said transform function, and measure hardness distribution of a surface layer as a surface layer property.
[0011] Moreover, it can replace with said energy distribution and sound pressure distribution or displacement distribution can also be introduced.
[0012] In the surface layer property measuring device with which the 2nd means measures the property of the surface layer of this analyte from two or more acoustic signals received from analyte A group delay operation means to compute the group delay between two acoustic signals of the arbitration which received in a different location among two or more acoustic signals received with a sound reception means to receive the acoustic signal which spreads said analyte front face, and this sound reception means, It is characterized by having a surface layer property conversion means to change into the surface layer property of this analyte the group delay calculated with this group delay operation means.
[0013] In this case, it can also constitute so that said sound reception means may serve as both functions including a means to transmit an acoustic signal.
[0014] Moreover, the related storage section by which said surface layer property conversion means was stored in the relation between hardening layer thickness and group delay, The related storage section in which hardening layer thickness and the relation of sonic rate of change [as opposed to a base material in constituting including the arithmetic circuit which calculates hardening layer thickness from said group delay based on said relation memorized by this related storage section ****] were stored, The related storage section in which it constituted including the arithmetic circuit which calculates hardening layer thickness from said group delay based on said relation memorized by this related storage section, or the hardness of analyte and the relation of group-velocity rate of change were stored, Based on said relation memorized by this related storage section, it can constitute from said group delay including the arithmetic circuit which calculates the hardness distribution on the front face of analyte, respectively.
[0015] Thus, if constituted, since group delay is the value which differentiated the phase with angular frequency, it can be computed regardless of the optionality of 2npi of a phase. It becomes unnecessary to introduce the solution means of measuring propagation path length by this.
[0016] Moreover, since the depth direction energy distribution is known when it is the formula which associates the depth direction distribution of the relative group delay of two or more frequencies, and relative group velocity for the change function which searches for a surface layer property according to the depth direction energy distribution of an acoustic signal, and the function which associates group-velocity rate of change and the physical-properties value of a surface layer, the depth direction distribution of relative group velocity is computable with the inverse transformation of this formula. Relative group velocity can compute the group-velocity rate of change to the base material group velocity of each class in accordance with the group velocity of a base material by the deepest part of the depth direction. Next, this group-velocity rate of change is changed into the physical-properties value of a surface layer based on said relation. in addition, that it can be with relativity here, it is one (propagation path length is not used for count) with strange propagation path length, and is because the rate itself is not necessarily computed.

[0017]
[Example] Hereafter, 1 operation gestalt of this invention is explained with reference to a drawing.
[0018] The mode of propagation uses the supersonic wave of a surface wave at drawing 1 , and the outline configuration of the surface layer property measuring device which measures the property of the hardening layer formed in the steel-materials front face is shown.
[0019] Layer thickness measurement equipment is equipped with a receiver 1, a receiver 2, the sound receive section 3, a digitizer 4, the group delay operation part 5, the surface layer property operation part 6, and the output section 7 in this drawing.
[0020] In drawing 1 , among the surface waves which spread the field where the hardening layer 11 was formed in the front face of steel materials 10, a receiver 1 receives the supersonic wave 8 refracted in the receiver 1 side concerned, and the receiver 2 left and arranged from the receiver 1 receives the supersonic wave 9 refracted in the receiver 2 side concerned. A supersonic wave 8 and a supersonic wave 9 are changed into an electrical signal, and are respectively changed into wave x(t) of a digital signal, and y (t) with the digitizer 4 which is amplified in the sound receive section 3 which consists of ultrasonic flow detectors etc., and consists of digital oscilloscopes etc. In a digitizer 4, this digital signal is held from a certain time of day about a supersonic wave 8 as wave x(t) of the digital signal of the time amount section (a "time window" is called hereafter) of constant width, and is held about a supersonic wave 9 as wave [of the digital signal of the time window which begins from the time of day which may differ from x (t)] y (t). In addition, although an operator may specify logging of a time window, as long as the near time amount in which a supersonic wave 8 and a supersonic wave 9 appear is known, the time window which fixed the time delay beforehand may be prepared.
[0021] In the group delay operation part 5, group delay tauU (omega (omega) is the angular frequency of a supersonic wave) of two or more round wave number of said wave x(t) and wave y (t) is calculated, and the property of a surface layer is calculated by the surface layer property operation part 6. The calculated result is outputted in the output section 7. Moreover, the logging location and width of face of a time window are inputted from the input section 12. In addition, the same receiver is satisfactory for a receiver 1 and a receive section 2. However, it is necessary to change the location of a receiver and to receive a surface wave in that case, in a different location.
[0022] The example of 1 configuration of the group delay operation part 5 and the function of each part are explained with reference to drawing 2 . A control circuit 501 reads wave x(t) as controlled the change-over machine 502 and shown in drawing 3 from a digitizer 4, and wave y (t), and memorizes them in the wave x (t) memory 503 and the wave y (t) memory 504, respectively. Next, a control circuit 501 controls the change-over machine 505, reads a wave and makes the fourier converter 506 carry out the Fourier transform of the wave y (t) for a wave to wave x(t) by delivery and the fourier converter 506 from the wave x (t) memory 503 and the wave y (t) memory 504. Wave x(t) by which the Fourier transform was carried out, and y (t) are respectively memorized by the X (omega) memory 508 and the Y (omega) memory 509 which are further chosen with the change-over vessel 507 controlled by the control circuit 501. Next, based on the data point memorized by the X (omega) memory 508 and the Y (omega) memory 509, the cross spectrum of X (omega) and Y (omega) is computed with the cross-spectrum computing element 510, and the result of an operation is memorized in the Z (omega) memory 511. In addition, the X (omega) memory 508, the Y (omega) memory 509, and the Z (omega) memory 511 consist of real number memory and imaginary memory, respectively. The cross spectrum memorized by the Z (omega) memory 511 is inputted phase characteristic computing-element 512, and the phase characteristic theta of a cross spectrum (omega) (refer to drawing 3) is computed. The computed migration property theta (omega) is differentiated with the phase differentiator 513, and a time delay is found. The propagation-time adder 514 adds time delay tauwindow between the time delay found with the phase differentiator 513, and the time window read from the wave **** condition memory 515. Group delay [as a result of being added] tauU (omega) is sent to the surface layer property operation part 6.
[0023] Procedure which asks for group delay tauU (omega) from the phase characteristic theta of a cross spectrum (omega) in the above function tauU =(omega) dtheta(omega)/d omega+tau window ... (3)
It is come out and expressed. This formula (3) shows that it can be computed even if group delay tauU (omega) has the optionality of 2npi in the phase theta of a cross spectrum (omega), since said 2npi is not contained as an element.
[0024] The surface layer property operation part 6 has an arithmetic circuit 61 and memory 62, as shown in drawing 4 . This example is an example which measures the thickness of a hardening layer as a property of a hardening layer. Hardening layer thickness and the relation of group delay are beforehand stored in said memory 62. As an example of this relation, artificers show the example of the experimental result which performed distance of a receiver 1 and a receiver 2 as about 57mm to the bottom of the equipment configuration of drawing 1 to drawing 5 . This drawing shows hardening layer thickness and the relation of the group delay of a 4.8MHz

surface wave, and group delay is shor[illegible] this drawing, so that hardening layer [illegible]ness becomes thick. That is, it turns out that group velocity is in the[illegible]ination which becomes so quick that [illegible]ening layer thickness is thick. From this, it can ask for this relation using the test piece whose thickness is two or more known kinds, and can ask for hardening layer thickness from group delay conversely by using as a calibration curve. In addition, the hardening layer thickness and the relation of group delay which are memorized in memory 62 are memorized about the wave number two or more rounds, and refer to the relation of a required frequency for them from memory 62. As for the frequency at this time, it is desirable to consider as the frequency which is extent the thickness of a hardening layer and whose order of wavelength correspond, and to use a probe with the large amplitude of that frequency region.

[0025] In addition, the relation between hardening layer thickness and the sonic rate of change to a base material is sufficient as the data memorized in memory 62. Moreover, three or more receivers may be prepared, the group delay of the supersonic wave received with two receivers of arbitration may be found, and same processing may be performed.

[0026] Thus, since group delay tauU (omega) computed from a formula (3) is changed into the property of a surface layer with this operation gestalt Even if the optionality of 2npi is in the phase theta of a cross spectrum (omega), are computable. The need of calculating the value of n of 2npi of a phase like the above-mentioned phase time delay by this, The function which measures correctly, the measurement conditions, for example, the propagation path length, of a phase time delay, measurement conditions where the condition and surface layer of a base material are formed, that only the difference within 2npi is produced in the phase contrast of received waves, etc. become unnecessary, and a measurement process and an equipment configuration can be simplified.

[0027] Here, the contents of concrete processing when measuring the property (thickness) of the hardening layer of the arithmetic circuit 61 of the surface layer property operation part 6 are explained. Drawing 6 is a flow chart which shows processing of the surface layer property operation part 6, and the relation of data flow.

[0028] In this processing, group delay tauU (omega) is read from the group delay operation part 5 at step 611 after processing initiation, further, the thickness of a hardening layer and the relation of group delay are read from memory (related storage section) 62, and group delay is changed into thickness from this relation. Subsequently, the thickness of the hardening layer changed from group delay tauU at step 612 (omega) is outputted to the output section 7, and it asks that it is processing termination at step 613, and if it is not termination, it will return to step 611. In addition, the thickness of a hardening layer and the relation of sonic rate of change are sufficient as the data read from memory (related storage section) 62 at step 611.

[0029] Next, an approach with it is explained. [effective when the hardness of a hardening layer approaches the hardness of a base material continuously (a hardening layer actually shows such a property in many cases)]

[0030] The surface layer property operation part 6 shown in drawing 4 can be constituted as follows, when measuring the depth direction distribution of a hardening layer as a property of a hardening layer. That is, the relation between hardness as shown in drawing 7 , and group-velocity rate of change is stored in memory 62. Hardness needs to measure this relation beforehand using a known test piece etc. Moreover, an arithmetic circuit 61 has the calculation function which changes group-velocity rate of change into hardness.

[0031] Here, the example of concrete processing in an arithmetic circuit 61 is explained. Drawing 8 is a flow chart which shows processing and data flow of an arithmetic circuit 61. Group delay tauU (k(omegak) =1-n) of two or more round wave number of n pieces is read from the group delay operation part 5 at step 614 after processing initiation. It divides into the false layer for count near the front face of analyte (a "count layer" is called hereafter) here, and is Un from U1 from the shallower one to order about the group velocity of each class. It sets. Here, a count layer is assumed to the depth from which the hardness of a hardening layer becomes equivalent to the hardness of a base material. As for the energy distribution of a surface wave, 90% or more of energy is distributed over one wave of within the limits under a front face, and it is known theoretically that the energy distribution will change exponentially (elastic wave theory PAGA88 written by Yasuo Sato). for this reason, the group velocity V of a certain wavelength (omega) -- energy distribution Pk of each count layer Group velocity Uk from -- weight -- if it assumes that it is computable on the average V(omegak) =sigma (Pk Uk) ... (4) (sigmaPk =1 [however,]) is materialized. In addition, sound pressure distribution, displacement distribution, etc. may be used instead of energy distribution. If a formula (4) is expressed about a total-session layer V=PU ... (5) It is expressed. nx1 matrix and U to which V expresses the group velocity of angular-frequency omegak (k=1-n) here are the count layer k (k=1-n) (nx1 matrix showing group velocity and P are the nxn matrices showing the energy distribution of angular-frequency omegak (k=1-n).). Energy distribution P will be the group velocity U of a count layer, if the group velocity V of angular-frequency omegak (k=1-n) is measured from the theory, since it is known. U=P-1V ... (6)

It comes out and asks.

[0032] However, since the propagation distance L has not measured correctly here, the group velocity V of each

frequency contains the strange multiplier L. Therefore, it depends for the group velocity U of a count layer on the strange multiplier L. However, since we can presume that the deepest count layer n in a count layer shows a group velocity comparable as a base material, group-velocity rate of change is calculated as a value by the strange multiplier L using the group velocity Un here. Group-velocity rate of change of each count layer (%) {(Uk-Un) /Un} *100 ... (7)
It is given by (however, k=1-n).
[0033] In the above procedure, group-velocity rate-of-change distribution of the depth direction is computed at step 614. Next, at step 615, the relation between group-velocity rate of change and hardness is read from memory (related storage section) 62, and group-velocity rate of change is changed into hardness. And hardening layer thickness is outputted to the output section 7 at step 616, and it asks that it is processing termination at step 617, and if it is not termination, it will return to step 614.
[0034] Here, although hardness distribution was searched for, if even the threshold hardness is defined as a hardening layer by making a certain hardness into a threshold, in step 615, it can ask for hardening layer thickness easily from hardness distribution.
[0035] Thus, according to this operation gestalt, since group-velocity rate-of-change distribution of the depth direction is searched for for the group velocity of the deepest count layer as criteria (group velocity of a base material) for every measurement, a probe can be arranged in the distance of arbitration for every measurement. Therefore, with the irregularity on the front face of analyte, when the location of the probe index to the analyte of an acoustic signal or an outgoing radiation point is unstable, or when a propagation path is a curved surface, measurement becomes possible.
[0036] In addition, in the above-mentioned operation gestalt, although the property of a surface layer was explained as the thickness of a surface layer, or hardness distribution of a surface layer, if it is the property which has group-velocity rate of change, such as a consistency, an elastic modulus, and residual stress, and correlation other than hardness in the rate of change of group velocity since it is the approach of evaluating a property secondarily as an index, it is theoretically measurable in the property by the same approach and equipment.
[0037] Next, other operation gestalten are explained. This operation gestalt is an example in the case of making an analyte front face generate a surface wave actively, and shows that outline configuration to drawing 9 .
[0038] Layer thickness measurement equipment is equipped with transceiver machine 1a, a receiver 2, sound transceiver section 3a, a digitizer 4, the group delay operation part 5, the surface layer property operation part 6, and the output section 7 in this drawing. With this layer thickness measurement equipment, transceiver machine 1a to ultrasonic 8a is transmitted in response to the transmitted pulse from sound transceiver section 3a which consists of ultrasonic flow detectors etc. Mode transformation of the ultrasonic 8a is carried out to a surface wave in an interface with steel materials 10, and it reflects at the edge of a wedge 12, and the surface wave which carried out mode transformation is divided into ultrasonic 8b again refracted in a wedge, and the supersonic wave 9 which passes through an edge and is received with another receiver 2, receives these, respectively, and is similarly processed by the same each part as the above-mentioned operation gestalt.
[0039] Thus, since it becomes unnecessary to newly prepare a sound transmitter when constituted, an equipment configuration can be simplified.
[0040]
[Effect of the Invention] Since the approach, the function, or the measurement conditions of calculating the value of n of 2npi of a phase like a phase time delay become unnecessary according to this invention, a measurement process and an equipment configuration can be simplified.
[0041] Moreover, according to this invention, a probe can be arranged in the distance of arbitration for every measurement. Therefore, with the irregularity on the front face of analyte, when the location of the outgoing radiation point of the probe index to the analyte of an acoustic signal is unstable, or when a propagation path is a curved surface, measurement becomes possible.
[0042] Furthermore, according to this invention, even when it is necessary to make an analyte front face generate a surface wave actively, it is not necessary to newly prepare a sound transmitter, and an equipment configuration becomes easy.

[Translation done.]

TECHNICAL FIELD

[Field of the Invention] This invention relates to the approach and equipment which measure the property of an analyte surface layer by un-destroying using an acoustic signal.

[Translation done.]

PRIOR ART

[Description of the Prior Art] The method of using sonic change of a surface wave as an approach of measuring the depth direction distribution of the thickness of a surface layer or the properties (hardness etc.) of a surface layer by un-destroying is learned. This approach uses that the acoustical property of a surface layer, i.e., the elastic modulus and consistency of a surface layer, differs from the base material section. That is, the rate that a surface wave spreads the surface layer and the base material section of a surface wave with the thickness of a surface layer since 90% or more of energy exists in the depth direction from the front face of analyte at one wave of within the limits changes. Consequently, it will be said that the acoustic velocity of a surface wave changes according to the thickness of a surface layer.
[0003] There is an approach indicated by JP,62-277554,A as a measuring method using this principle. By this approach, the analyte front face was made to spread a surface wave, it was received by one side, acoustic velocity was searched for from the propagation time in the meantime, and the thickness of a surface layer is measured from the sonic rate of change on the basis of the acoustic velocity of a base material. However, in a surface wave, the phenomenon which the way of a RF spreads according to the distributed phenomenon in which acoustic velocity changes with frequencies, more quickly than low frequency arises, and it changes or spreads with propagation. For this reason, by the above-mentioned approach, highly precise propagation-time measurement is difficult.
[0004] As a means to solve this, there is a method of searching for acoustic velocity from the propagation time for every frequency, and the approach announced by nondestructive inspection (39th volume No. 2 pp. 99 -103) "nondestructive evaluation of the surface layer by the Rayleigh wave" is learned as this example. By this approach, the phase velocity of two or more frequencies is measured, and the depth direction distribution of the elastic modulus of a surface layer is calculated from that rate of change.

[Translation done.]

EFFECT OF THE INVENTION

[Effect of the Invention] Since the approach, the function, or the measurement conditions of calculating the value of n of 2npi of a phase like a phase time delay become unnecessary according to this invention, a measurement process and an equipment configuration can be simplified.
[0041] Moreover, according to this invention, a probe can be arranged in the distance of arbitration for every measurement. Therefore, with the irregularity on the front face of analyte, when the location of the outgoing radiation point of the probe index to the analyte of an acoustic signal is unstable, or when a propagation path is a curved surface, measurement becomes possible.
[0042] Furthermore, according to this invention, even when it is necessary to make an analyte front face generate a surface wave actively, it is not necessary to newly prepare a sound transmitter, and an equipment configuration becomes easy.

[Translation done.]

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] By the way, although the phase velocity of the wave number is measured two or more rounds with the above-mentioned conventional technique, measurement of the phase time delay between the points receiving [2] is needed for this. About both the received waves received at said point receiving [2], a phase time delay is computed from the phase contrast of a certain frequency component. This process is explained with reference to drawing 10 . In this drawing, the wave of the angular frequency omega in the receiving point 2 presupposes that there is phase lag of thetar (omega) to the wave of the angular frequency omega in the receiving point 1. however, ** which the trough A of the receiving point 1 is the trough B of the receiving point 2 in fact, or is trough B' or are other troughs which 2pi left ready several times -- it is not clear. That is, the optionality of 2npi (n is an integer) exists in phase contrast theta (omega), and it is phase contrast theta (omega). theta(omega) =thetar+(omega) 2npi ... (1)
It can express. On the other hand, it is phase time delay taup (omega). taup =(omega) theta (omega) / omega ... (2)
Since it is come out and computed, it is too influenced of the optionality of 2npi. For this reason, it is necessary to solve this problem with another means.
[0006] So, by the well-known example of said latter, where the condition and surface layer of a base material are formed, a means to ask the known acoustic velocity and the known propagation path length of a base material for near phase contrast, and to ask only for the gap between - pi-pi from the phase contrast by measurement from a premise that only the difference within 2npi is produced in the phase contrast of received waves is adopted. However, when the case where the location of transmission or reception is unstable, and a propagation path are curved surfaces and measurement of propagation path length is difficult, near phase contrast cannot be known with said means, as a result measurement of the elastic modulus (hardness) of a surface layer becomes difficult.
[0007] This invention was made in view of the actual condition of such a conventional technique, and the purpose is in offering the approach and equipment which can measure the property of a surface layer, even if propagation path length is strange.

[Translation done.]

MEANS

[Means for Solving the Problem] In the surface layer property measuring method with which the 1st means measures the property of the surface layer of this analyte from two or more acoustic signals received from analyte in order to attain the above-mentioned purpose The group delay of the frequency of the arbitration between two acoustic signals in said two or more acoustic signals is found. It is characterized by changing the group delay of the frequency of the arbitration between said two acoustic signals into a surface layer property, and measuring the property of the surface layer of analyte from the relation between the group delay found beforehand and said surface layer property.
[0009] In this case, the transform function changed into the property of a surface layer from group delay is introduced as relation of the property of said group delay and surface layer for which it asked beforehand, and hardening layer thickness is measured as a surface layer property.
[0010] Moreover, when measuring the depth direction distribution of the physical properties of a surface layer as said surface layer property, the frequencies of said arbitration are two or more frequencies, introduce the transform function which associates the group delay of two or more of said frequencies, and the depth direction distribution of said physical properties according to the depth direction energy distribution as said transform function, and measure hardness distribution of a surface layer as a surface layer property.
[0011] Moreover, it can replace with said energy distribution and sound pressure distribution or displacement distribution can also be introduced.
[0012] This invention is characterized by the surface layer property measuring device with which the 2nd means measures the property of the surface layer of this analyte from two or more acoustic signals received from analyte possessing the following. A sound reception means to receive the acoustic signal which spreads said analyte front face A group delay operation means to compute the group delay between two acoustic signals of the arbitration which received in a different location among two or more acoustic signals received with this sound reception means A surface layer property conversion means to change into the surface layer property of this analyte the group delay calculated with this group delay operation means
[0013] In this case, it can also constitute so that said sound reception means may serve as both functions including a means to transmit an acoustic signal.
[0014] Moreover, the related storage section by which said surface layer property conversion means was stored in the relation between hardening layer thickness and group delay, The related storage section in which hardening layer thickness and the relation of sonic rate of change [as opposed to a base material in constituting including the arithmetic circuit which calculates hardening layer thickness from said group delay based on said relation memorized by this related storage section ****] were stored, The related storage section in which it constituted including the arithmetic circuit which calculates hardening layer thickness from said group delay based on said relation memorized by this related storage section, or the hardness of analyte and the relation of group-velocity rate of change were stored, Based on said relation memorized by this related storage section, it can constitute from said group delay including the arithmetic circuit which calculates the hardness distribution on the front face of analyte, respectively.

EXAMPLE

[Example] Hereafter, 1 operation gestalt of this invention is explained with reference to a drawing.
[0018] The mode of propagation uses the supersonic wave of a surface wave at drawing 1 , and the outline configuration of the surface layer property measuring device which measures the property of the hardening layer formed in the steel-materials front face is shown.
[0019] Layer thickness measurement equipment is equipped with a receiver 1, a receiver 2, the sound receive section 3, a digitizer 4, the group delay operation part 5, the surface layer property operation part 6, and the output section 7 in this drawing.
[0020] In drawing 1 , among the surface waves which spread the field where the hardening layer 11 was formed in the front face of steel materials 10, a receiver 1 receives the supersonic wave 8 refracted in the receiver 1 side concerned, and the receiver 2 left and arranged from the receiver 1 receives the supersonic wave 9 refracted in the receiver 2 side concerned. A supersonic wave 8 and a supersonic wave 9 are changed into an electrical signal, and are respectively changed into wave x(t) of a digital signal, and y (t) with the digitizer 4 which is amplified in the sound receive section 3 which consists of ultrasonic flow detectors etc., and consists of digital oscilloscopes etc. In a digitizer 4, this digital signal is held from a certain time of day about a supersonic wave 8 as wave x(t) of the digital signal of the time amount section (a "time window" is called hereafter) of constant width, and is held about a supersonic wave 9 as wave [of the digital signal of the time window which begins from the time of day which may differ from x (t)] y (t). In addition, although an operator may specify logging of a time window, as long as the near time amount in which a supersonic wave 8 and a supersonic wave 9 appear is known, the time window which fixed the time delay beforehand may be prepared.
[0021] In the group delay operation part 5, group delay tauU (omega (omega) is the angular frequency of a supersonic wave) of two or more round wave number of said wave x(t) and wave y (t) is calculated, and the property of a surface layer is calculated by the surface layer property operation part 6. The calculated result is outputted in the output section 7. Moreover, the logging location and width of face of a time window are inputted from the input section 12. In addition, the same receiver is satisfactory for a receiver 1 and a receive section 2. However, it is necessary to change the location of a receiver and to receive a surface wave in that case, in a different location.
[0022] The example of 1 configuration of the group delay operation part 5 and the function of each part are explained with reference to drawing 2 . A control circuit 501 reads wave x(t) as controlled the change-over machine 502 and shown in drawing 3 from a digitizer 4, and wave y (t), and memorizes them in the wave x (t) memory 503 and the wave y (t) memory 504, respectively. Next, a control circuit 501 controls the change-over machine 505, reads a wave and makes the fourier converter 506 carry out the Fourier transform of the wave y (t) for a wave to wave x(t) by delivery and the fourier converter 506 from the wave x (t) memory 503 and the wave y (t) memory 504. Wave x(t) by which the Fourier transform was carried out, and y (t) are respectively memorized by the X (omega) memory 508 and the Y (omega) memory 509 which are further chosen with the change-over vessel 507 controlled by the control circuit 501. Next, based on the data point memorized by the X (omega) memory 508 and the Y (omega) memory 509, the cross spectrum of X (omega) and Y (omega) is computed with the cross-spectrum computing element 510, and the result of an operation is memorized in the Z (omega) memory 511. In addition, the X (omega) memory 508, the Y (omega) memory 509, and the Z (omega) memory 511 consist of real number memory and imaginary memory, respectively. The cross spectrum memorized by the Z (omega) memory 511 is inputted phase characteristic computing-element 512, and the phase characteristic theta of a cross spectrum (omega) (refer to drawing 3) is computed. The computed migration property theta (omega) is differentiated with the phase differentiator 513, and a time delay is found. The propagation-time adder 514 adds time delay tauwindow between the time delay found with the phase differentiator 513, and the time window read from the wave **** condition memory 515. Group delay [as a result of being added] tauU (omega) is sent to the surface layer property operation part 6.

[0023] Procedure which asks for gro[illegible]delay tauU (omega) from the phase ch[illegible]teristic theta of a cross spectrum (omega) in the above func[illegible] tauU =(omega) dtheta(omega)/d omeg[illegible]tau window ... (3)
It is come out and expressed. This formula (3) shows that it can be computed even if group delay tauU (omega) has the optionality of 2npi in the phase theta of a cross spectrum (omega), since said 2npi is not contained as an element.
[0024] The surface layer property operation part 6 has an arithmetic circuit 61 and memory 62, as shown in drawing 4 . This example is an example which measures the thickness of a hardening layer as a property of a hardening layer. Hardening layer thickness and the relation of group delay are beforehand stored in said memory 62. As an example of this relation, artificers show the example of the experimental result which performed distance of a receiver 1 and a receiver 2 as about 57mm to the bottom of the equipment configuration of drawing 1 to drawing 5 . This drawing shows hardening layer thickness and the relation of the group delay of a 4.8MHz surface wave, and group delay is short in this drawing, so that hardening layer thickness becomes thick. That is, it turns out that group velocity is in the inclination which becomes so quick that hardening layer thickness is thick. From this, it can ask for this relation using the test piece whose thickness is two or more known kinds, and can ask for hardening layer thickness from group delay conversely by using as a calibration curve. In addition, the hardening layer thickness and the relation of group delay which are memorized in memory 62 are memorized about the wave number two or more rounds, and refer to the relation of a required frequency for them from memory 62. As for the frequency at this time, it is desirable to consider as the frequency which is extent the thickness of a hardening layer and whose order of wavelength correspond, and to use a probe with the large amplitude of that frequency region.
[0025] In addition, the relation between hardening layer thickness and the sonic rate of change to a base material is sufficient as the data memorized in memory 62. Moreover, three or more receivers may be prepared, the group delay of the supersonic wave received with two receivers of arbitration may be found, and same processing may be performed.
[0026] Thus, since group delay tauU (omega) computed from a formula (3) is changed into the property of a surface layer with this operation gestalt Even if the optionality of 2npi is in the phase theta of a cross spectrum (omega), are computable. The need of calculating the value of n of 2npi of a phase like the above-mentioned phase time delay by this, The function which measures correctly, the measurement conditions, for example, the propagation path length, of a phase time delay, measurement conditions where the condition and surface layer of a base material are formed, that only the difference within 2npi is produced in the phase contrast of received waves, etc. become unnecessary, and a measurement process and an equipment configuration can be simplified.
[0027] Here, the contents of concrete processing when measuring the property (thickness) of the hardening layer of the arithmetic circuit 61 of the surface layer property operation part 6 are explained. Drawing 6 is a flow chart which shows processing of the surface layer property operation part 6, and the relation of data flow.
[0028] In this processing, group delay tauU (omega) is read from the group delay operation part 5 at step 611 after processing initiation, further, the thickness of a hardening layer and the relation of group delay are read from memory (related storage section) 62, and group delay is changed into thickness from this relation. Subsequently, the thickness of the hardening layer changed from group delay tauU at step 612 (omega) is outputted to the output section 7, and it asks that it is processing termination at step 613, and if it is not termination, it will return to step 611. In addition, the thickness of a hardening layer and the relation of sonic rate of change are sufficient as the data read from memory (related storage section) 62 at step 611.
[0029] Next, an approach with it is explained. [effective when the hardness of a hardening layer approaches the hardness of a base material continuously (a hardening layer actually shows such a property in many cases)]
[0030] The surface layer property operation part 6 shown in drawing 4 can be constituted as follows, when measuring the depth direction distribution of a hardening layer as a property of a hardening layer. That is, the relation between hardness as shown in drawing 7 , and group-velocity rate of change is stored in memory 62. Hardness needs to measure this relation beforehand using a known test piece etc. Moreover, an arithmetic circuit 61 has the calculation function which changes group-velocity rate of change into hardness.
[0031] Here, the example of concrete processing in an arithmetic circuit 61 is explained. Drawing 8 is a flow chart which shows processing and data flow of an arithmetic circuit 61. Group delay tauU (k(omegak) =1-n) of two or more round wave number of n pieces is read from the group delay operation part 5 at step 614 after processing initiation. It divides into the false layer for count near the front face of analyte (a "count layer" is called hereafter) here, and is Un from U1 from the shallower one to order about the group velocity of each class. It sets. Here, a count layer is assumed to the depth from which the hardness of a hardening layer becomes equivalent to the hardness of a base material. As for the energy distribution of a surface wave, 90% or more of energy is distributed over one wave of within the limits under a front face, and it is known theoretically that the energy distribution will change exponentially (elastic wave theory PAGA88 written by Yasuo Sato). for this reason, the

group velocity V of a certain wavelength (omega) -- energy distribution Pk of each count layer Group velocity Uk from -- weight -- if it assumes that it is computable on the average V(omegak)=sigma (Pk Uk) ... (4)
(sigmaPk =1 [however,]) is materialized. In addition, sound pressure distribution, displacement distribution, etc. may be used instead of energy distribution. If a formula (4) is expressed about a total-session layer V=PU ... (5)
It is expressed. nx1 matrix and U to which V expresses the group velocity of angular-frequency omegak (k=1-n) here are the count layer k (k=1-n) (nx1 matrix showing group velocity and P are the nxn matrices showing the energy distribution of angular-frequency omegak (k=1-n).). Energy distribution P will be the group velocity U of a count layer, if the group velocity V of angular-frequency omegak (k=1-n) is measured from the theory, since it is known. U=P-1V ... (6)
It comes out and asks.
[0032] However, since the propagation distance L has not measured correctly here, the group velocity V of each frequency contains the strange multiplier L. Therefore, it depends for the group velocity U of a count layer on the strange multiplier L. However, since it can presume that the deepest count layer n in a count layer shows a group velocity comparable as a base material, group-velocity rate of change is calculated as a value by the strange multiplier L using the group velocity Un here. Group-velocity rate of change of each count layer (%) {(Uk-Un) /Un} *100 ... (7)
It is given by (however, k=1-n).
[0033] In the above procedure, group-velocity rate-of-change distribution of the depth direction is computed at step 614. Next, at step 615, the relation between group-velocity rate of change and hardness is read from memory (related storage section) 62, and group-velocity rate of change is changed into hardness. And hardening layer thickness is outputted to the output section 7 at step 616, and it asks that it is processing termination at step 617, and if it is not termination, it will return to step 614.
[0034] Here, although hardness distribution was searched for, if even the threshold hardness is defined as a hardening layer by making a certain hardness into a threshold, in step 615, it can ask for hardening layer thickness easily from hardness distribution.
[0035] Thus, according to this operation gestalt, since group-velocity rate-of-change distribution of the depth direction is searched for for the group velocity of the deepest count layer as criteria (group velocity of a base material) for every measurement, a probe can be arranged in the distance of arbitration for every measurement. Therefore, with the irregularity on the front face of analyte, when the location of the probe index to the analyte of an acoustic signal or an outgoing radiation point is unstable, or when a propagation path is a curved surface, measurement becomes possible.
[0036] In addition, in the above-mentioned operation gestalt, although the property of a surface layer was explained as the thickness of a surface layer, or hardness distribution of a surface layer, if it is the property which has group-velocity rate of change, such as a consistency, an elastic modulus, and residual stress, and correlation other than hardness in the rate of change of group velocity since it is the approach of evaluating a property secondarily as an index, it is theoretically measurable in the property by the same approach and equipment.
[0037] Next, other operation gestalten are explained. This operation gestalt is an example in the case of making an analyte front face generate a surface wave actively, and shows that outline configuration to drawing 9 .
[0038] Layer thickness measurement equipment is equipped with transceiver machine 1a, a receiver 2, sound transceiver section 3a, a digitizer 4, the group delay operation part 5, the surface layer property operation part 6, and the output section 7 in this drawing. With this layer thickness measurement equipment, transceiver machine 1a to ultrasonic 8a is transmitted in response to the transmitted pulse from sound transceiver section 3a which consists of ultrasonic flow detectors etc. Mode transformation of the ultrasonic 8a is carried out to a surface wave in an interface with steel materials 10, and it reflects at the edge of a wedge 12, and the surface wave which carried out mode transformation is divided into ultrasonic 8b again refracted in a wedge, and the supersonic wave 9 which passes through an edge and is received with another receiver 2, receives these, respectively, and is similarly processed by the same each part as the above-mentioned operation gestalt.
[0039] Thus, since it becomes unnecessary to newly prepare a sound transmitter when constituted, an equipment configuration can be simplified.

[Translation done.]

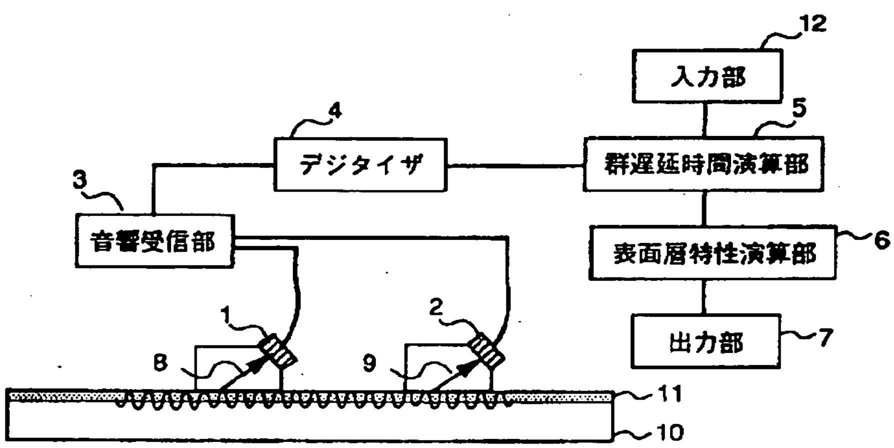
DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the outline block diagram of the measuring device of the surface layer property concerning the operation gestalt of this invention.
[Drawing 2] It is the block diagram showing the configuration of the group delay operation part in drawing 1 .
[Drawing 3] It is the explanatory view showing the computation of the group delay in the group delay operation part in drawing 1 .
[Drawing 4] It is the block diagram showing the configuration of the surface layer property operation part in drawing 1 .
[Drawing 5] It is the explanatory view showing change of the group delay over hardening layer thickness.
[Drawing 6] It is the flow chart which shows the procedure of the surface layer property operation part in drawing 4 .
[Drawing 7] It is the explanatory view showing change of the group-velocity rate of change to hardness.
[Drawing 8] It is the flow chart which shows other procedure of the surface layer property operation part in drawing 4 .
[Drawing 9] It is the outline block diagram of the measuring device of the surface layer property concerning other operation gestalten of this invention.
[Drawing 10] It is the explanatory view showing the optionality of 2npi of a phase time delay.
[Description of Notations]
1 Receiver
2 Receiver
3 Sound Receive Section
4 Digitizer
5 Group Delay Operation Part
6 Surface Layer Property Operation Part
7 Output Section
8 Supersonic Wave
9 Supersonic Wave
10 Steel Materials
11 Hardening Layer
12 Input Section
61 Arithmetic Circuit
62 Memory (Related Storage Section)

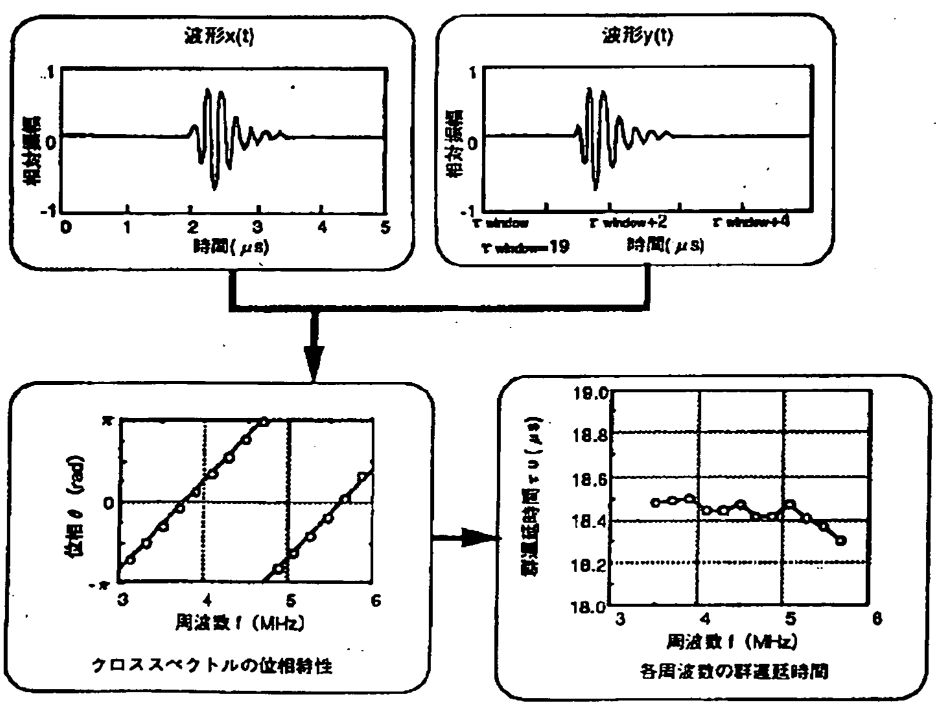
[Translation done.]

DRAWINGS

[Drawing 1]
【図１】

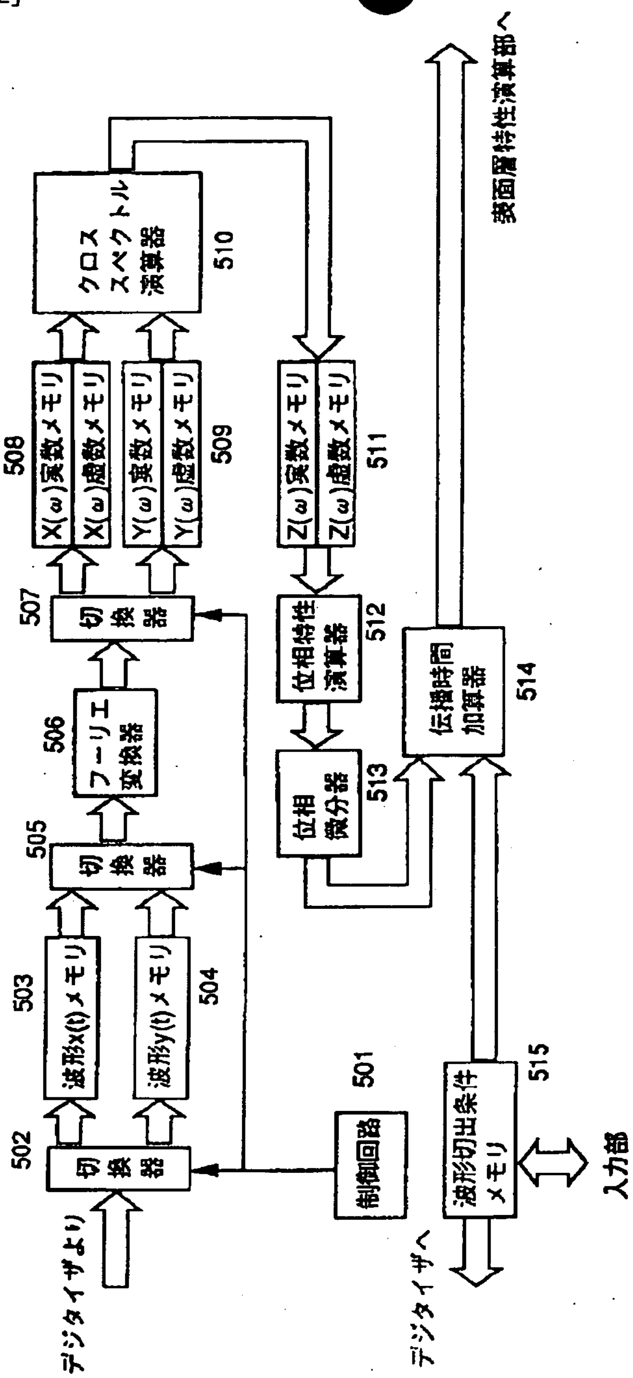


[Drawing 3]
【図３】



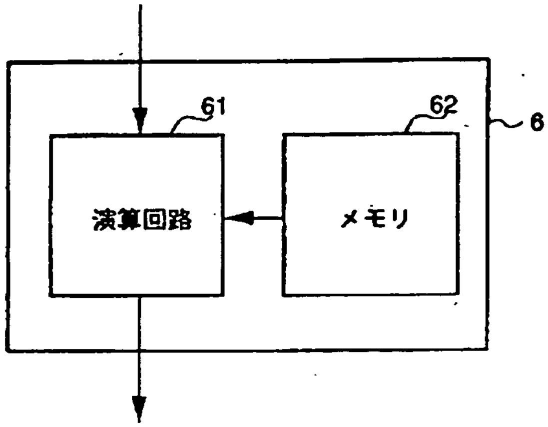
[Drawing 2]

【図2】

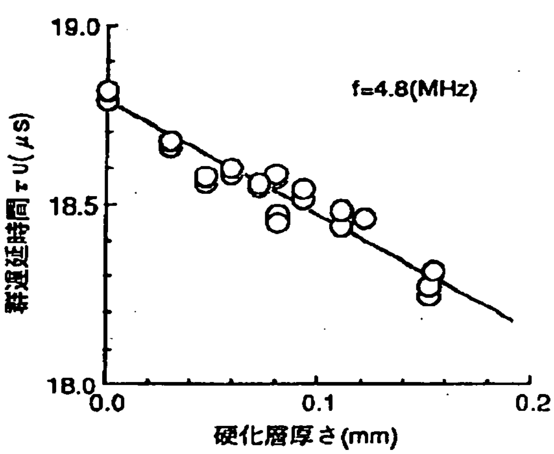


[Drawing 4]

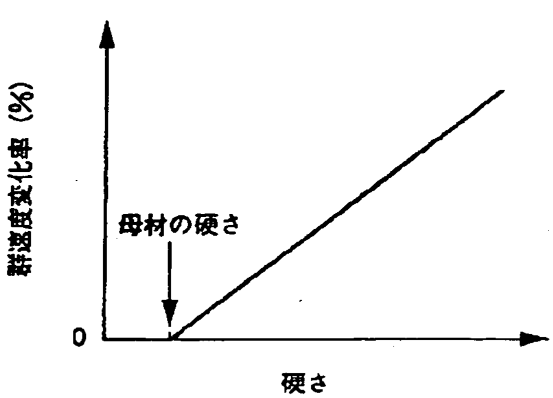
【図４】



[Drawing 5]
【図５】

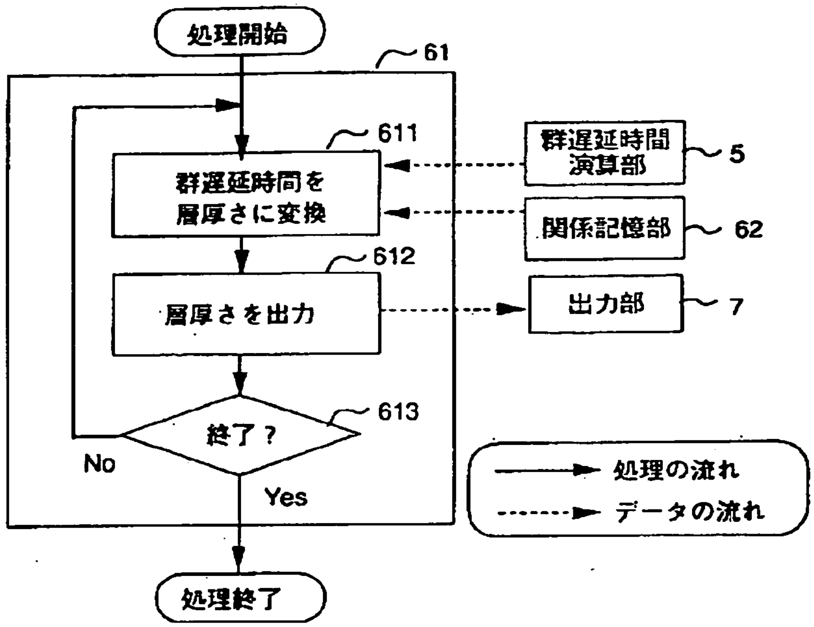


[Drawing 7]
【図７】



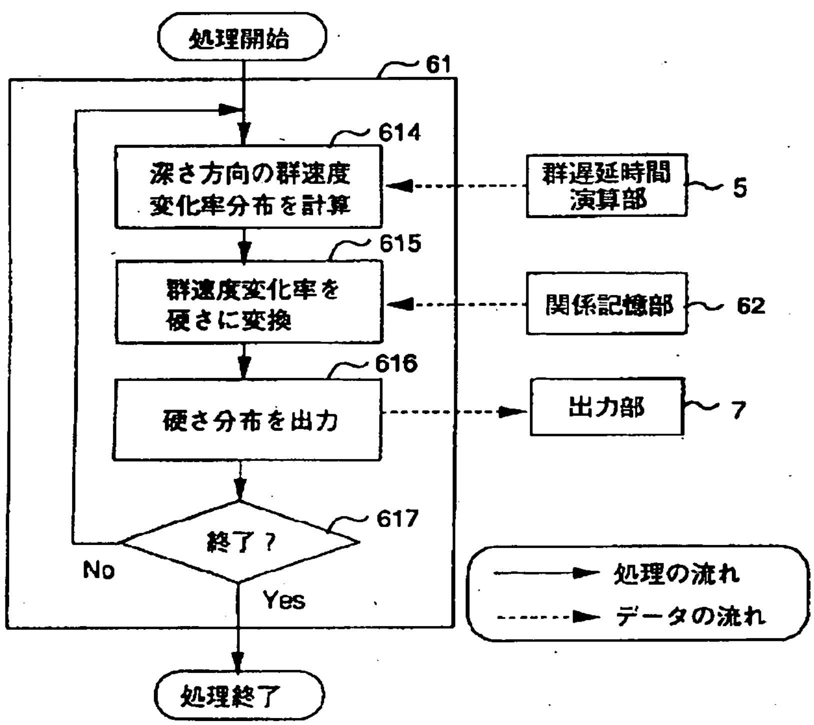
[Drawing 6]

【図６】



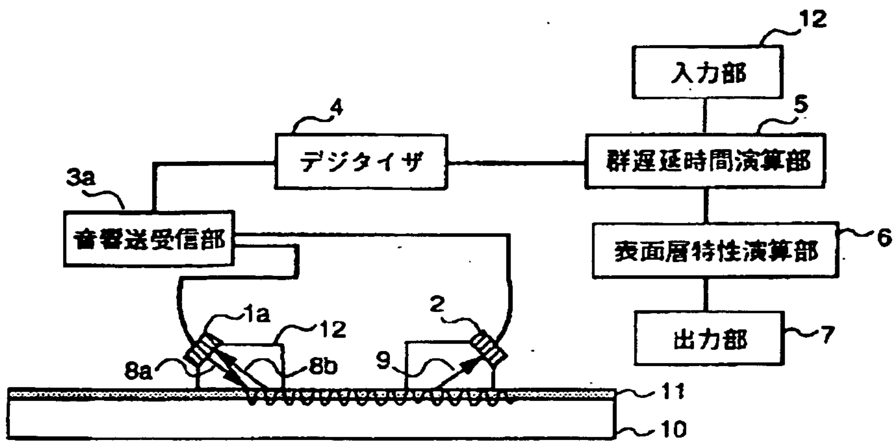
[Drawing 8]

【図８】

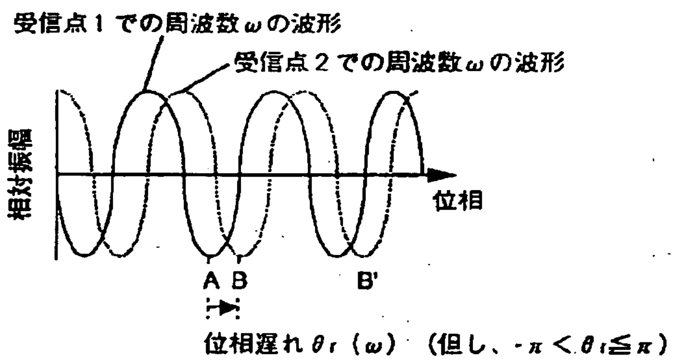


[Drawing 9]

【図９】



[Drawing 10]
【図10】



位相差 θ（ω）＝ θ_r（ω）$+2n\pi$
（nは整数）

位相遅延時間 τ_P（ω）＝ $\dfrac{\theta(\omega)}{\omega}$

[Translation done.]

CORRECTION OR AMENDMENT

[Kind of official gazette] Printing of amendment by the convention of 2 of Article 17 of Patent Law
[Section partition] The 1st partition of the 6th section
[Publication date] December 15, Heisei 12 (2000. 12.15)

[Publication No.] JP,9-196900,A
[Date of Publication] July 31, Heisei 9 (1997. 7.31)
[Annual volume number] Open patent official report 9-1969
[Application number] Japanese Patent Application No. 8-7501
[The 7th edition of International Patent Classification]

G01N 29/18

[FI]

G01N 29/18

[Procedure revision]
[Filing Date] August 19, Heisei 11 (1999. 8.19)
[Procedure amendment 2]
[Document to be Amended] Specification
[Item(s) to be Amended] 0010
[Method of Amendment] Deletion
[Procedure amendment 3]
[Document to be Amended] Specification
[Item(s) to be Amended] 0011
[Method of Amendment] Deletion

[Translation done.]

(19)日本国特許庁（ＪＰ）　(12) 公開特許公報（Ａ）　(11)特許出願公開番号

特開平9－196900

(43)公開日　平成９年(1997)７月31日

(51)Int.Cl.⁶	識別記号	庁内整理番号	ＦＩ	技術表示箇所
Ｇ０１Ｎ　29/18			Ｇ０１Ｎ　29/18	

審査請求　未請求　請求項の数12　ＯＬ　（全 11 頁）

(21)出願番号　特願平8－7501

(22)出願日　平成８年(1996)１月19日

(71)出願人　000005108
株式会社日立製作所
東京都千代田区神田駿河台四丁目６番地

(72)発明者　永島　良昭
茨城県日立市大みか町七丁目２番１号　株式会社日立製作所電力・電機開発本部内

(72)発明者　小池　正浩
茨城県日立市大みか町七丁目２番１号　株式会社日立製作所電力・電機開発本部内

(72)発明者　川又　啓人
茨城県日立市幸町三丁目１番１号　株式会社日立製作所日立工場内

(74)代理人　弁理士　武　顕次郎

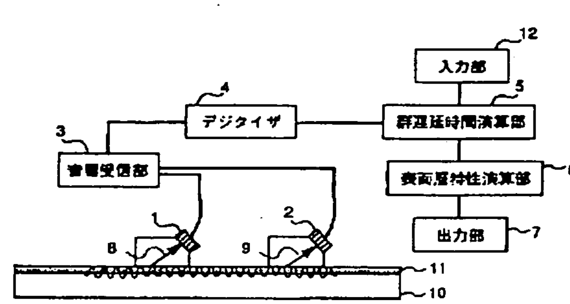
(54)【発明の名称】　表面層特性の測定方法および装置

(57)【要約】

【課題】　音響信号の伝播経路長が未知の場合においても、被検体の表面層の特性を測定できる方法および装置を提供する。

【解決手段】　鋼材１０の表面に硬化層１１が形成された面を伝播する表面波のうち、受信器１側に屈折する超音波８を受信器１で受信する。受信器２は受信器１から離れて配置し、受信器２側に屈折する超音波９を受信する。超音波８と超音波９は、電気信号に変換され、超音波探傷器等で構成される音響受信部３で増幅され、デジタルオシロスコープ等で構成されるデジタイザ４でデジタル信号に変換される。このデジタル信号を使って群遅延時間演算部５で超音波８と超音波９の複数周波数の群遅延時間を計算し、表面層特性演算部６で表面層の特性を計算する。

【図１】



【特許請求の範囲】
【請求項１】　被検体から受信した複数の音響信号から、該被検体の表面層の特性を測定する表面層特性測定方法において、
前記複数の音響信号の中の二つの音響信号間の任意の周波数の群遅延時間を求め、あらかじめ求めておいた群遅延時間と前記表面層特性との関係に基づいて、求められた前記二つの音響信号間の任意の周波数の群遅延時間を表面層特性に変換し、被検体の表面層の特性を測定することを特徴とする表面層特性の測定方法。
【請求項２】　前記あらかじめ求めておいた群遅延時間と表面層特性との関係が、群遅延時間から表面層の特性に変換する変換関数であることを特徴とする請求項１記載の表面層特性の測定方法。
【請求項３】　前記表面層特性が硬化層厚さであることを特徴とする請求項１または２記載の表面層特性の測定方法。
【請求項４】　前記表面層特性が表面層の物性の深さ方向分布であり、前記任意の周波数は複数の周波数であって、前記変換関数が前記複数の周波数の群遅延時間と前記物性の深さ方向分布とを深さ方向エネルギー分布によって関連づける変換関数であることを特徴とする請求項２記載の表面層特性測定方法。
【請求項５】　前記表面層特性が表面層の物性の深さ方向分布であり、前記任意の周波数は複数の周波数であって、前記変換関数が前記複数の周波数の群遅延時間と前記物性の深さ方向分布とを深さ方向音圧分布によって関連づける変換関数であることを特徴とする請求項２記載の表面層特性測定方法。
【請求項６】　前記表面層特性が表面層の物性の深さ方向分布であり、前記任意の周波数は複数の周波数であって、前記変換関数が前記複数の周波数の群遅延時間と前記物性の深さ方向分布とを深さ方向変位分布によって関連づける変換関数であることを特徴とする請求項２記載の表面層特性測定方法。
【請求項７】　前記表面層特性が表面層の硬さ分布であることを特徴とする請求項４ないし６のいずれか１項に記載の表面層特性測定方法。
【請求項８】　被検体から受信した複数の音響信号から、該被検体の表面層の特性を測定する表面層特性測定装置において、
前記被検体表面を伝播する音響信号を受信する音響受信手段と、
この音響受信手段で受信した複数の音響信号のうち異なる位置で受信した任意の二つの音響信号間の群遅延時間を算出する群遅延時間演算手段と、
この群遅延時間演算手段で演算した群遅延時間を該被検体の表面層特性に変換する表面層特性変換手段と、、を備えていることを特徴とする表面層特性測定装置。
【請求項９】　前記音響受信手段が、音響信号を送信する手段を含んでなることを特徴とする特徴とする請求項８記載の表面層特性測定装置。
【請求項１０】　前記表面層特性変換手段が、硬化層厚さと群遅延時間との関係が格納されたメモリと、このメモリに記憶された前記関係に基づいて前記群遅延時間から硬化層厚さを演算する演算回路とを含んでなることを特徴とする請求項８記載の表面層特性測定装置。
【請求項１１】　前記表面層特性変換手段が、硬化層厚さと母材に対する音速変化率の関係が格納されたメモリと、このメモリに記憶された前記関係に基づいて前記群遅延時間から硬化層厚さを演算する演算回路とを含んでなることを特徴とする請求項８記載の表面層特性測定装置。
【請求項１２】　前記表面層特性変換手段が、被検体の硬さと群速度変化率の関係が格納されたメモリと、このメモリに記憶された前記関係に基づいて前記群速度変化率から被検体表面の硬さ分布を演算する演算回路とを含んでなることを特徴とする請求項８記載の表面層特性測定装置。
【発明の詳細な説明】
【０００１】
【発明の属する技術分野】本発明は、音響信号を使用して被検体表面層の特性を非破壊で測定する方法および装置に関する。
【０００２】
【従来の技術】表面層の厚さ、もしくは表面層の性質（硬さ等）の深さ方向分布を非破壊で計測する方法として表面波の音速変化を利用する方法が知られている。この方法は、表面層の音響的性質すなわち表面層の弾性係数や密度が母材部と異なることを利用するものである。すなわち、表面波は被検体の表面から深さ方向に一波長の範囲内に９０％以上のエネルギーが存在するため、表面層の厚さによって表面波の表面層と母材部を伝播する割合が変化する。この結果、表面層の厚さに応じて表面波の音速が変化するということになる。
【０００３】この原理を用いた測定法として特開昭６２－２７７５５４に開示された方法がある。この方法では、被検体表面に表面波を伝播させて一方でそれを受信し、その間の伝播時間から音速を求め、母材の音速を基準とした音速変化率から表面層の厚さを測定している。しかし、表面波では周波数によって音速が異なる分散現象により高周波のほうが低周波より速く伝播する現象が生じ、伝播に伴って変化したり広がったりする。このため、上記の方法では、高精度な伝播時間測定は困難である。
【０００４】これを解決する手段として、周波数毎の伝播時間から音速を求める方法があり、この例として、非破壊検査（第３９巻第２号ｐｐ．９９－１０３）「レーリー波による表面層の非破壊評価」で発表された方法が知られている。この方法では、複数の周波数の位相速度

を計測し、その変化率から表面層の弾性係数の深さ方向分布を計算するようになっている。

【0005】

【発明が解決しようとする課題】ところで、上記従来技術では複数周波数の位相速度を計測するようになっているが、これには、２受信点間の位相遅延時間の測定が必要となる。位相遅延時間は前記２受信点で受信した両受信波について、ある周波数成分の位相差から算出する。この過程を図１０を参照して説明する。同図において、受信点１での角周波数ωの波形に対し、受信点２での角周波数ωの波形は、$\theta_r(\omega)$ の位相遅れがあるとする。しかし、実際には受信点１の谷Ａが受信点２の谷Ｂであるか谷Ｂ’であるか、あるいは２πの整数倍離れた他の谷であるは明らかでない。すなわち、位相差 $\theta(\omega)$ には２ｎπ（ｎは整数）の任意性が存在し、位相差 $\theta(\omega)$ は、

$$\theta(\omega)=\theta_r(\omega)+2n\pi \quad \cdots(1)$$

と表現できる。一方、位相遅延時間 $\tau_p(\omega)$ は、

$$\tau_p(\omega)=\theta(\omega)/\omega \quad \cdots(2)$$

で算出されるため、やはり、２ｎπの任意性の影響を受ける。このために、この問題を別の手段で解決する必要がある。

【０００６】そこで、前記後者の公知例では、母材の状態と表面層が形成された状態では受信波間の位相差に２ｎπ以内の差しか生じないとの前提から、既知の母材の音速と伝播経路長からおおよその位相差を求め、その位相差からの－π～πの間のずれのみを計測によって求める手段を採用している。しかしながら、送信や受信の位置が不安定である場合や伝播経路が曲面である場合など、伝播経路長が測定困難な場合には、前記手段によりおおよその位相差を知ることができず、ひいては表面層の弾性係数（硬さ）の測定が困難になる。

【０００７】本発明は、このような従来技術の実情に鑑みてなされたもので、その目的は、伝播経路長が未知であっても、表面層の特性を測定できる方法および装置を提供することにある。

【０００８】

【課題を解決するための手段】上記目的を達成するため、第１の手段は、被検体から受信した複数の音響信号から、該被検体の表面層の特性を測定する表面層特性測定方法において、前記複数の音響信号の中の二つの音響信号間の任意の周波数の群遅延時間を求め、あらかじめ求めておいた群遅延時間と前記表面層特性との関係から、前記二つの音響信号間の任意の周波数の群遅延時間を表面層特性に変換し、被検体の表面層の特性を測定することを特徴としている。

【０００９】この場合、前記あらかじめ求めておいた群遅延時間と表面層との特性の関係として、例えば群遅延時間から表面層の特性に変換する変換関数を導入し、表面層特性として硬化層厚さを測定する。

【００１０】また、前記表面層特性として表面層の物性の深さ方向分布を測定する場合、前記任意の周波数は複数の周波数であって、前記変換関数として前記複数の周波数の群遅延時間と前記物性の深さ方向分布とを深さ方向エネルギー分布によって関連づける変換関数を導入し、表面層特性として表面層の硬さ分布を測定する。

【００１１】また、前記エネルギー分布に代えて音圧分布あるいは変位分布を導入することもできる。

【００１２】第２の手段は、被検体から受信した複数の音響信号から、該被検体の表面層の特性を測定する表面層特性測定装置において、前記被検体表面を伝播する音響信号を受信する音響受信手段と、この音響受信手段で受信した複数の音響信号のうち異なる位置で受信した任意の二つの音響信号間の群遅延時間を算出する群遅延時間演算手段と、この群遅延時間演算手段で演算した群遅延時間を該被検体の表面層特性に変換する表面層特性変換手段とを備えていることを特徴としている。

【００１３】この場合、前記音響受信手段が音響信号を送信する手段を含み、両機能を兼ねるように構成することもできる。

【００１４】また、前記表面層特性変換手段を、硬化層厚さと群遅延時間との関係が格納された関係記憶部と、この関係記憶部に記憶された前記関係に基づいて前記群遅延時間から硬化層厚さを演算する演算回路とを含んで構成したり、硬化層厚さと母材に対する音速変化率の関係が格納された関係記憶部と、この関係記憶部に記憶された前記関係に基づいて前記群遅延時間から硬化層厚さを演算する演算回路とを含んで構成したり、被検体の硬さと群速度変化率の関係が格納された関係記憶部と、この関係記憶部に記憶された前記関係に基づいて前記群遅延時間から被検体表面の硬さ分布を演算する演算回路とを含んでそれぞれ構成できる。

【００１５】このように構成すると、群遅延時間は位相を角周波数で微分した値であるため、位相の２ｎπの任意性に関係なく算出することができるようになる。これによって、伝播経路長を測定する等の解決手段を導入する必要がなくなる。

【００１６】また、表面層特性を求める変化関数を、複数の周波数の相対群遅延時間と相対群速度の深さ方向分布を音響信号の深さ方向エネルギー分布によって関連づける計算式と、群速度変化率と表面層の物性値を関連付ける関数とすると、深さ方向エネルギー分布は既知であるので、この計算式の逆変換により相対群速度の深さ方向分布を算出することができる。相対群速度は深さ方向の最深部で母材の群速度に一致し、各層の母材群速度に対する群速度変化率が算出できる。次に、この群速度変化率を前記関係に基づいて表面層の物性値に変換する。

なお、ここで相対というは、伝播経路長が未知である（計算に伝播経路長を使用していない）ので、速度そのものを算出しているわけではないからである。

【００１７】

【実施例】以下、図面を参照し、本発明の一実施形態について説明する。

【００１８】図１に、伝播モードが表面波の超音波を使用し、鋼材表面に形成した硬化層の特性を測定する表面層特性測定装置の概略構成を示す。

【００１９】同図において、層厚さ測定装置は、受信器１と、受信器２と、音響受信部３と、デジタイザ４と、群遅延時間演算部５と、表面層特性演算部６と、出力部７とを備えている。

【００２０】図１において、鋼材１０の表面に硬化層１１が形成された面を伝播する表面波のうち、受信器１は当該受信器１側に屈折した超音波８を受信し、受信器１から離れて配置された受信器２は当該受信器２側に屈折した超音波９を受信する。超音波８と超音波９は電気信号に変換され、超音波探傷器等で構成される音響受信部３で増幅され、デジタルオシロスコープ等で構成されるデジタイザ４で各々デジタル信号の波形ｘ（ｔ）とｙ（ｔ）に変換される。このデジタル信号はデジタイザ４中で、超音波８についてはある時刻から一定幅の時間区間（以下、「時間窓」と称する）のデジタル信号の波形ｘ（ｔ）として保持され、超音波９についてはｘ（ｔ）と異なってもよい時刻から始まる時間窓のデジタル信号の波形ｙ（ｔ）として保持される。なお、時間窓の切り出しはオペレータが指定してもよいが、超音波８と超音波９の現われるおおよその時間がわかっていれば、予め遅延時間を固定した時間窓を用意してもよい。

【００２１】群遅延時間演算部５では、前記波形ｘ（ｔ）と波形ｙ（ｔ）の複数周波数の群遅延時間τ_{g}（ω）（ωは超音波の角周波数）を計算し、表面層特性演算部６で表面層の特性を計算する。計算された結果は、出力部７で出力される。また、時間窓の切り出し位置や幅は入力部１２から入力される。なお、受信器１と受信部２は同一の受信器でもよい。しかし、その場合には、受信器の位置を変えて、異なる位置で表面波を受信する必要がある。

【００２２】群遅延時間演算部５の一構成例と各部の機能について図２を参照して説明する。制御回路５０１は切換器５０２を制御してデジタイザ４から図３に示すような波形ｘ（ｔ）と波形ｙ（ｔ）を読み出し、それぞれ波形ｘ（ｔ）メモリ５０３、波形ｙ（ｔ）メモリ５０４に記憶する。次に、制御回路５０１は、切換器５０５を制御して波形ｘ（ｔ）メモリ５０３と波形ｙ（ｔ）メモリ５０４から、波形を読み出してフーリエ変換器５０６に波形を送り、フーリエ変換器５０６で波形ｘ（ｔ）と波形ｙ（ｔ）をフーリエ変換させる。フーリエ変換された波形ｘ（ｔ）、ｙ（ｔ）は、さらに、制御回路５０１によって制御される切換器５０７によって選択されるＸ（ω）メモリ５０８とＹ（ω）メモリ５０９に各々記憶される。次に、Ｘ（ω）メモリ５０８とＹ（ω）メモリ５０９に記憶された波形データに基づいてクロススペクトル演算器５１０でＸ（ω）とＹ（ω）のクロススペクトルを算出し、演算結果をＺ（ω）メモリ５１１に記憶する。なお、Ｘ（ω）メモリ５０８、Ｙ（ω）メモリ５０９およびＺ（ω）メモリ５１１はそれぞれ実数メモリと虚数メモリからなっている。Ｚ（ω）メモリ５１１に記憶されたクロススペクトルは位相特性演算器５１２入力され、クロススペクトルの位相特性θ（ω）（図３参照）が算出される。算出された移送特性θ（ω）は、位相微分器５１３で微分され、遅延時間が求められる。伝播時間加算器５１４は、位相微分器５１３で求められた遅延時間と波形切出条件メモリ５１５から読み出された時間窓間の遅延時間τ_{window}を加算する。加算された結果、すなわち群遅延時間τ_{g}（ω）は、表面層特性演算部６に送られる。

【００２３】以上の機能の中で、クロススペクトルの位相特性θ（ω）から群遅延時間τ_{g}（ω）を求める手続きは、

$$\tau_{g}(\omega) = d\theta(\omega)/d\omega + \tau_{window} \quad \cdots (3)$$

で表される。この式（３）から群遅延時間τ_{g}（ω）は、前記２ｎπが要素として含まれないのでクロススペクトルの位相θ（ω）に２ｎπの任意性があったとしても算出可能であることがわかる。

【００２４】表面層特性演算部６は、図４に示すように演算回路６１とメモリ６２を有する。この例は、硬化層の特性として硬化層の厚さを測定する例である。前記メモリ６２には、硬化層厚さと群遅延時間の関係があらかじめ格納されている。この関係の一例として、発明者らが図１の装置構成の下に、受信器１と受信器２との距離を約５７ｍｍとして行なった実験結果の例を図５に示す。同図は、硬化層厚さと４．８ＭＨｚの表面波の群遅延時間の関係を示しており、この図では硬化層厚さが厚くなるほど群遅延時間が短くなっている。すなわち、群速度は硬化層厚さが厚いほど速くなる傾向にあることがわかる。このことから、厚さが既知の複数種類の試験片を使用してこの関係を求め、校正曲線として用いることで、逆に群遅延時間から硬化層厚さを求めることができる。なお、メモリ６２に記憶する硬化層厚さと群遅延時間の関係は、複数周波数について記憶しておき、必要な周波数の関係をメモリ６２から参照してもよい。このときの周波数は、硬化層の厚さと波長のオーダが一致する程度の周波数とし、その周波数域の振幅が大きい探触子を用いるのが望ましい。

【００２５】なお、メモリ６２に記憶するデータは、硬化層厚さと母材に対する音速変化率の関係でもよい。ま

た、受信器を３個以上用意して、任意の２個の受信器で受信した超音波の群遅延時間を求め、同様の処理を行なってもよい。

【００２６】このように本実施形態では、式（３）から算出する群遅延時間τ_{ij}（ω）を表面層の特性に変換するので、クロススペクトルの位相θ（ω）に２ｎπの任意性があっても算出可能であり、これによって前述の位相遅延時間のように位相の２ｎπのｎの値を求める必要や、位相遅延時間の計測条件、例えば、伝播経路長を正確に測定する機能や、母材の状態と表面層が形成された状態では受信波間の位相差に２ｎπ以内の差しか生じないとの計測条件などが不要となり、測定過程や装置構成を簡略化することができる。

【００２７】ここで、表面層特性演算部６の演算回路６１の硬化層の特性（厚さ）を測定するときの具体的処理内容について説明する。図６は表面層特性演算部６の処理とデータの流れの関係を示すフローチャートである。

【００２８】この処理では、処理開始後、ステップ６１１で群遅延時間演算部５から群遅延時間τ_{ij}（ω）を読み込み、さらに、メモリ（関係記憶部）６２から硬化層の厚さと群遅延時間の関係を読み込んで、この関係から群遅延時間を厚さに変換する。次いで、ステップ６１２で群遅延時間τ_{ij}（ω）から変換された硬化層の厚さを出力部７に出力し、ステップ６１３で処理終了か否かの問い合わせを行ない、終了でなければステップ６１１に戻る。なお、ステップ６１１でメモリ（関係記憶部）６２から読み込むデータは、硬化層の厚さと音速変化率の関係でもよい。

【００２９】次に、硬化層の硬さが、連続的に母材の硬さに近づく場合（実際、硬化層はこのような性質を示すことが多い）に有効な方法について説明する。

【００３０】図４に示す表面層特性演算部６は、硬化層の特性として硬化層の深さ方向分布を測定する場合には、次のように構成することができる。すなわち、メモリ６２には、図７に示すような硬さと群速度変化率の関係を格納しておく。この関係は、硬さが既知な試験片等を用いて予め測定しておく必要がある。また、演算回路６１は、群速度変化率を硬さに変換する演算機能を有する。

【００３１】ここで、演算回路６１での具体的処理例について説明する。図８は、演算回路６１の処理とデータの流れを示すフローチャートである。処理開始後、ステップ６１４で群遅延時間演算部５から、ｎ個の複数周波数の群遅延時間τ_{ij}（ω_k）（ｋ＝１～ｎ）を読み込む。ここで、被検体の表面近傍を計算のための擬似的な層（以下、「計算層」と称する）に分割し、各層の群速度を浅い方から順にU_1からU_nとおく。ここで、計算層は、硬化層の硬さが母材の硬さと同等となる深さまで仮定する。表面波のエネルギー分布は、表面下一波長の範囲内にエネルギーの９０％以上が分布し、そのエネルギー分布は指数関数的に変化することが理論的に知られている（佐藤泰夫著　弾性波動論　ＰＡＧＡ８８）。このため、ある波長の群速度Ｖ（ω）が、各計算層のエネルギー分布P_kと群速度U_kから重み平均的に算出できると仮定すれば、

$$V(\omega_k)=\Sigma(P_k U_k) \quad \cdots(4)$$

（ただし、$\Sigma P_k=1$）が成立する。なお、エネルギー分布の代わりに、音圧分布、変位分布等を用いてもよい。式（４）を全計算層に関して表現すると、

$$V=PU \quad \cdots(5)$$

と表される。ここで、Ｖは角周波数ω_k（ｋ＝１～ｎ）の群速度を表わすｎ×１行列、Ｕは計算層ｋ（（ｋ＝１～ｎ）の群速度を表わすｎ×１行列、Ｐは角周波数ω_k（ｋ＝１～ｎ）のエネルギー分布を表わすｎ×ｎ行列である。エネルギー分布Ｐは理論より既知であるので、角周波数ω_k（ｋ＝１～ｎ）の群速度Ｖを測定すれば、計算層の群速度Ｕは、

$$U=P^{-1}V \quad \cdots(6)$$

で求められる。

【００３２】しかし、ここでは伝播距離Ｌが正確に測定できていないために、各周波数の群速度Ｖは未知係数Ｌを含む。したがって、計算層の群速度Ｕも未知係数Ｌに依存する。しかしながら、計算層のなかで最深の計算層ｎは母材と同程度の群速度を示すと推定できるので、ここでの群速度Ｕｎを用いて未知係数Ｌによらない値として群速度変化率を計算する。各計算層の群速度変化率（％）は、

$$\{(U_k-U_n)/U_n\}*100 \quad \cdots(7)$$

（ただし、ｋ＝１～ｎ）で与えられる。

【００３３】以上の手続きにより、ステップ６１４では深さ方向の群速度変化率分布を算出する。次に、ステップ６１５で、メモリ（関係記憶部）６２から群速度変化率と硬さの関係を読み込み、群速度変化率を硬さに変換する。そして、ステップ６１６で出力部７に硬化層厚さを出力し、ステップ６１７で処理終了か否かの問い合わせを行ない、終了でなければステップ６１４に戻る。

【００３４】ここでは、硬さ分布を求めたが、ある硬さをしきい値として、そのしきい値硬さまでを硬化層と定義すれば、ステップ６１５において、硬さ分布から硬化層厚さを容易に求めることができる。

【００３５】このように本実施形態によれば、測定毎に最深の計算層の群速度を基準（母材の群速度）として、

深さ方向の群速度変化率分布を求めるので、探触子を測定毎に任意の距離に配置できる。したがって、被検体表面の凹凸により、音響信号の被検体への入射点や出射点の位置が不安定な場合や、伝播経路が曲面である場合においても測定が可能になる。

【0036】なお、上記実施形態においては、表面層の特性を表面層の厚さ、あるいは表面層の硬さ分布として説明したが、原理的には群速度の変化率を指標として二次的に特性を評価する方法なので、硬さの他にも密度、弾性係数、残留応力など群速度変化率と相関がある特性であれば、同様の方法および装置により、その特性を測定可能である。

【0037】次に、他の実施形態について説明する。この実施形態は、被検体表面に能動的に表面波を発生させる必要がある場合の例であり、その概略構成を図９に示す。

【0038】同図において、層厚さ測定装置は、送受信器１ａと、受信器２と、音響送受信部３ａと、デジタイザ４と、群遅延時間演算部５と、表面層特性演算部６と、出力部７とを備えている。この層厚さ測定装置では、超音波探傷器等で構成される音響送受信部３ａからの送信パルスを受けて、送受信器１ａから超音波８ａが送信される。超音波８ａは、鋼材１０との境界面で表面波にモード変換し、モード変換した表面波はくさび１２の端部で反射し、再びくさび内に屈折する超音波８ｂと、端部を通過して別の受信器２で受信される超音波９とに分かれ、これらをそれぞれ受信して前述の実施形態と同様の各部によって同様に処理される。

【0039】このように構成すると、新たに音響送信器を用意する必要がなくなるので、装置構成を簡単にすることができる。

【0040】

【発明の効果】本発明によれば、位相遅延時間のように位相の２ｎπのｎの値を求める方法、機能もしくは計測条件が不要となるので、測定過程や装置構成を簡略化することができる。

【0041】また本発明によれば、探触子を測定毎に任意の距離に配置できる。したがって、被検体表面の凹凸により、音響信号の被検体への入射点の出射点の位置が不安定な場合や、伝播経路が曲面である場合においても測定が可能になる。

【0042】更に本発明によれば、被検体表面に能動的に表面波を発生させる必要がある場合でも、新たに音響送信器を用意する必要がなく、装置構成が簡単になる。

【図面の簡単な説明】

【図１】本発明の実施形態に係る表面層特性の測定装置の概略構成図である。

【図２】図１における群遅延時間演算部の構成を示すブロック図である。

【図３】図１における群遅延時間演算部における群遅延時間の計算過程を示す説明図である。

【図４】図１における表面層特性演算部の構成を示すブロック図である。

【図５】硬化層厚さに対する群遅延時間の変化を示す説明図である。

【図６】図４における表面層特性演算部の処理手順を示すフローチャートである。

【図７】硬さに対する群速度変化率の変化を示す説明図である。

【図８】図４における表面層特性演算部の他の処理手順を示すフローチャートである。

【図９】本発明の他の実施形態に係る表面層特性の測定装置の概略構成図である。

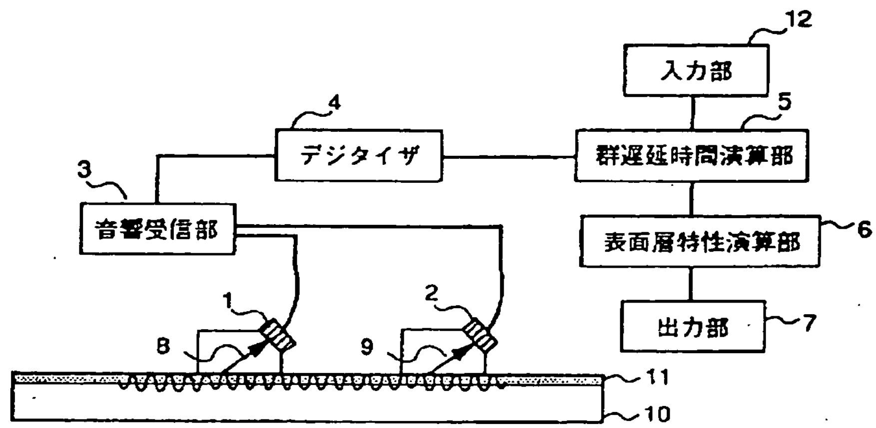
【図１０】位相遅延時間の２ｎπの任意性を示す説明図である。

【符号の説明】

１　受信器
２　受信器
３　音響受信部
４　デジタイザ
５　群遅延時間演算部
６　表面層特性演算部
７　出力部
８　超音波
９　超音波
１０　鋼材
１１　硬化層
１２　入力部
６１　演算回路
６２　メモリ（関係記憶部）

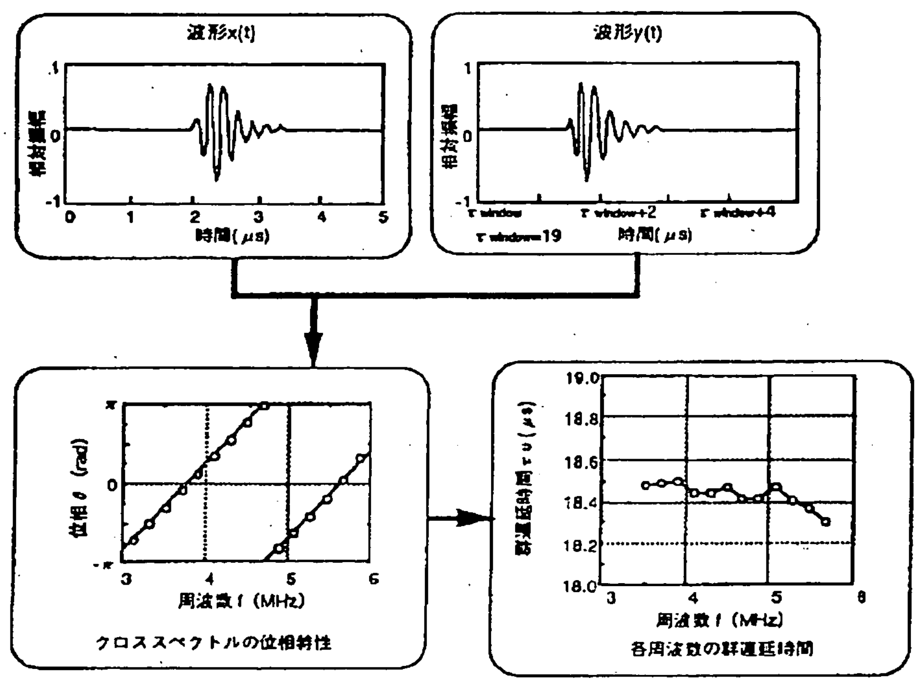
【図1】

【図1】

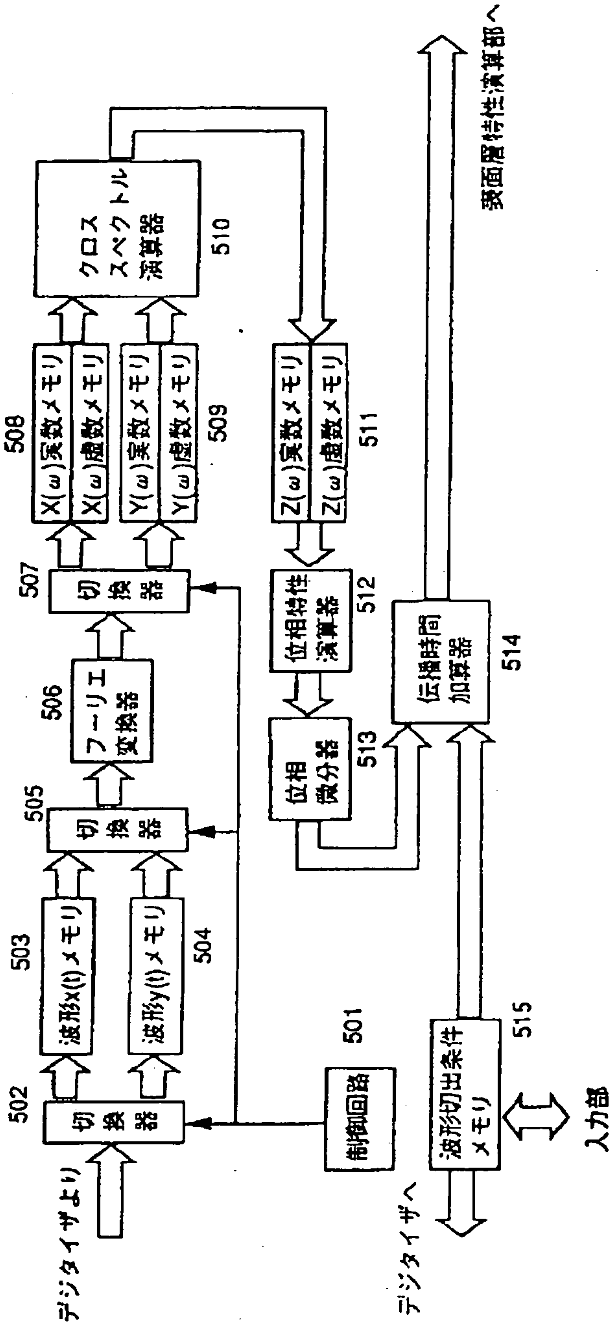

入力部
デジタイザ
群遅延時間演算部
音響受信部
表面層特性演算部
出力部
1
2
3
4
5
6
7
8
9
10
11
12

【図3】

【図3】


波形x(t)
相対振幅
時間(μs)
波形y(t)
相対振幅
時間(μs)
位相θ (rad)
周波数 f (MHz)
クロススペクトルの位相特性
群遅延時間τu (μs)
周波数 f (MHz)
各周波数の群遅延時間

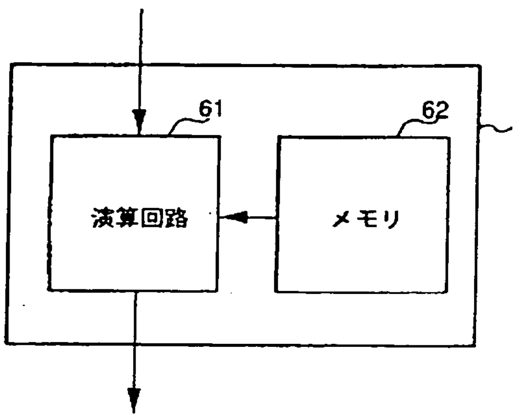
【図2】


デジタイザより
切換器
502
制御回路
501
波形x(t)メモリ
503
波形y(t)メモリ
504
切換器
505
フーリエ変換器
506
切換器
507
X(ω)実数メモリ
X(ω)虚数メモリ
508
Y(ω)実数メモリ
Y(ω)虚数メモリ
509
クロススペクトル演算器
510
Z(ω)実数メモリ
Z(ω)虚数メモリ
511
位相特性演算器
512
位相微分器
513
伝播時間加算器
514
波形切出条件メモリ
515
デジタイザへ
入力部
表面層特性演算部へ

【図2】

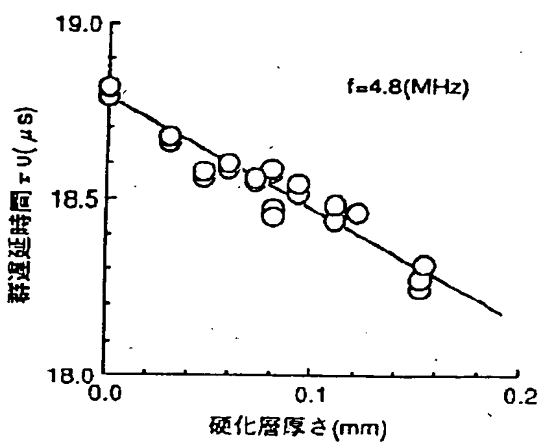
【図4】

【図4】



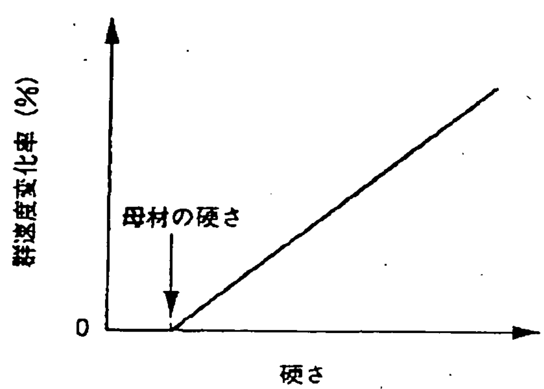
【図5】

【図5】



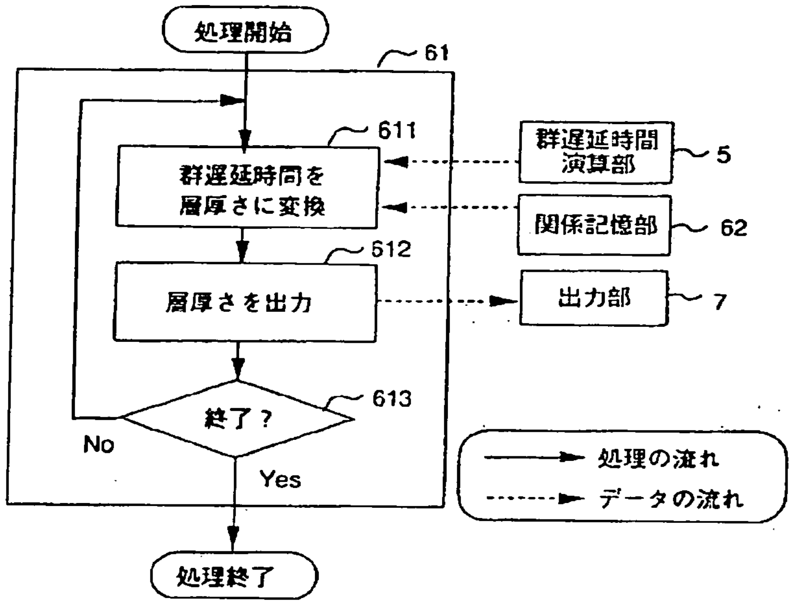
【図7】

【図7】



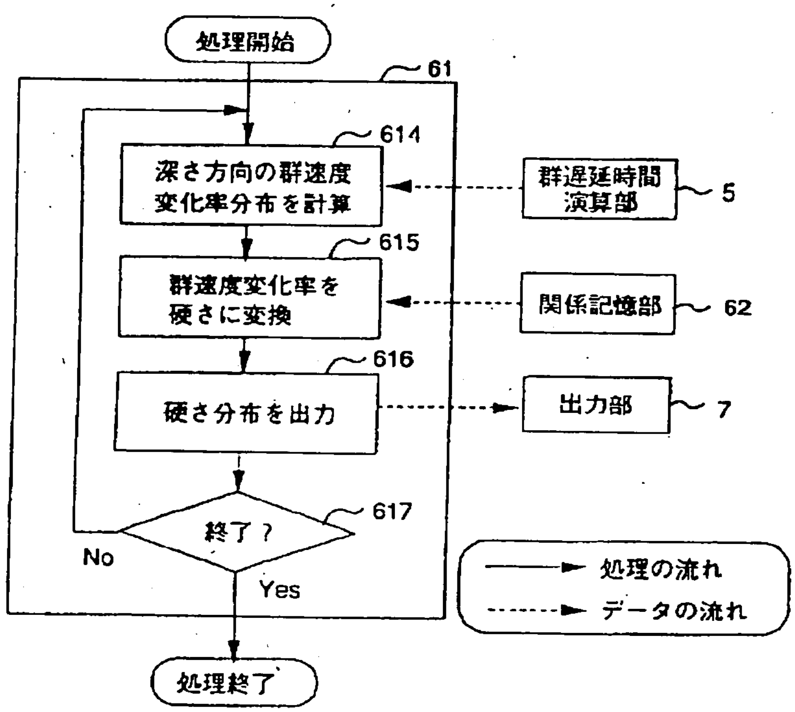
【図6】

【図6】


処理開始
61
611
群遅延時間を
層厚さに変換
群遅延時間
演算部
5
関係記憶部
62
612
層厚さを出力
出力部
7
613
終了？
No
Yes
処理の流れ
データの流れ
処理終了

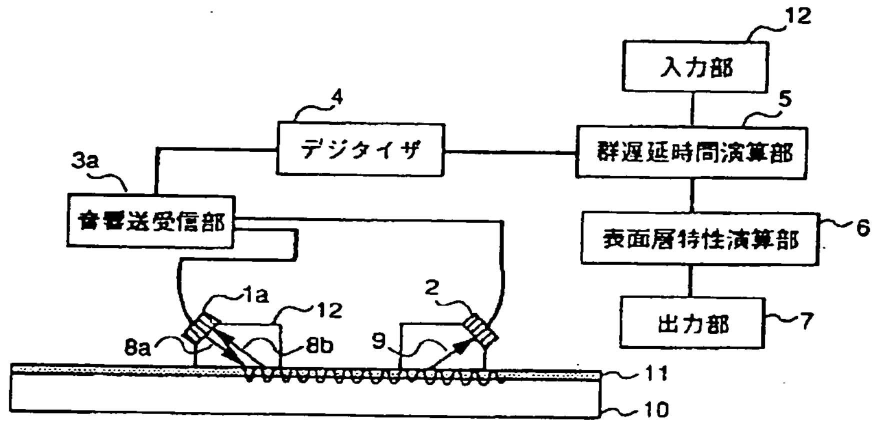
【図8】

【図8】


処理開始
61
614
深さ方向の群速度
変化率分布を計算
群遅延時間
演算部
5
615
群速度変化率を
硬さに変換
関係記憶部
62
616
硬さ分布を出力
出力部
7
617
終了？
No
Yes
処理の流れ
データの流れ
処理終了

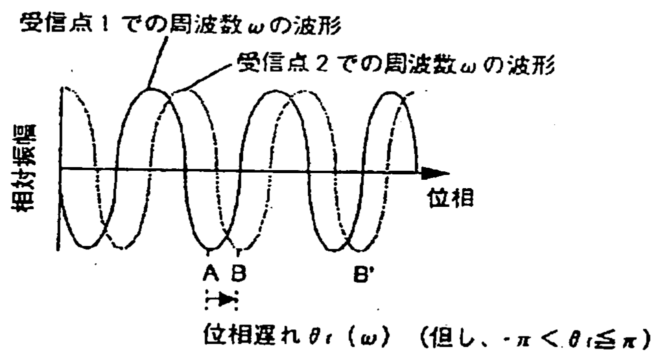
【図9】

【図9】



【図10】

【図10】



位相差 $\theta(\omega) = \theta_r(\omega) + 2n\pi$
（nは整数）

位相遅延時間 $\tau p(\omega) = \dfrac{\theta(\omega)}{\omega}$

【公報種別】特許法第１７条の２の規定による補正の掲載
【部門区分】第６部門第１区分
【発行日】平成１２年１２月１５日（２０００．１２．１５）

【公開番号】特開平９－１９６９００
【公開日】平成９年７月３１日（１９９７．７．３１）
【年通号数】公開特許公報９－１９６９
【出願番号】特願平８－７５０１
【国際特許分類第７版】
G01N 29/18
【ＦＩ】
G01N 29/18

【手続補正書】
【提出日】平成１１年８月１９日（１９９９．８．１９）
【手続補正２】
【補正対象書類名】明細書
【補正対象項目名】００１０
【補正方法】削除
【手続補正３】
【補正対象書類名】明細書
【補正対象項目名】００１１
【補正方法】削除